

NASA Human Research Program Behavioral Health and Performance Element (BHP)

The goal of NASA BHP is to identify, characterize, and prevent or reduce behavioral health and performance risks associated with space travel, exploration, and return to terrestrial life

Behavioral Health and Performance *Operations* Group

The NASA Behavioral Health and Performance Operations Group (BHP Ops) supports astronauts and their families before, during, and after a long-duration mission (LDM) on the ISS. BHP Ops provides ISS crews with services such as preflight training (e.g., psychological factors of LDM, psychological support, cross-cultural); preflight, in-flight, and postflight support services, including counseling for astronauts and their families; and psychological support such as regular care packages and a voice-over IP phone system between crew members and their families to facilitate real-time one-on-one communication.

ISS astronauts regularly recognize the relevant and helpful support provided to them by BHP Ops.

BHP and Long-Duration Exploration Missions

With future exploration missions beyond ISS, BHP faces the challenge of adapting its crew support services without the benefit of real-time communication and with infrequent carepackage delivery.

Crew members will live and work in remote, isolated, confined, and extreme environments. Missions will extend beyond six months, reaching one year, or even up to three years. Communication with those back home will be limited; external surroundings will be austere, and the crew member habitat will offer little in the way of comfort and variety.

These challenges compel BHP to study the potential risks associated with exploration space flight and to develop and implement countermeasures that support the psychological well being of crew members.

Behavioral Health and Performance *Research* Element Human Health Risks

In preparation for such exploration missions to distant planetary surfaces, the BHP Element (BHP) conducts and supports research to address gaps in knowledge and gaps in mitigation related to three interconnected human health risks. These risks include:

- “Sleep Risk”: *Risk of Performance Errors due to Sleep Loss, Fatigue, Circadian Desynchronization, and Work Overload;*
- “Team Risk”: *Risk of Performance Errors Due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation;*
- “B-Med Risk”: *Risk of Adverse Behavioral Health and Risk of Psychiatric Conditions*

A strategy of “prevention” will become increasingly important during long-duration exploration missions when crews will be more autonomous. Therefore, among other gaps within the “B-Med Risk”, BHP has identified the following gap:

***Gap Bmed1:** What are the optimal methods to enhance behavioral health and prevent decrements before, during, and after space flight missions?*

To address this gap, part of BHP’s future research plan involves the identification and development of potential countermeasure approaches related to:

- Sensory Stimulation Augmentation Tools *(to address the potential for sensory deprivation)*;
- Non-medication Stress Prevention Countermeasures;
- Food (freshness, variety) effects on Behavioral Health and Performance

The Use of Plant Life to Promote Psychological Well-Being

It is proposed that plant life can serve as a useful preventive stress countermeasure, as well as a behavioral health enhancing method, for exploration missions. Plants provide:

- Sensory input (sight, taste, smell, touch) *(Figures 1 & 2)*
- A stress-reducing hobby and aesthetic appeal
- A psychological link to Earth



Figure 1: Plant life on ISS Expedition 31



ISS006E44969

Figure 2: A flower grown on ISS Expedition 6

Other groups at NASA are investigating methods through which plants can be grown and harvested in space for bio-regenerative life support systems and food production. Because this resource will likely be available to astronauts for these purposes, it will be valuable to understand how the presence of plant life can benefit a crew’s behavioral health.

Connection to Earth

Astronauts on current missions have enjoyed photographing Earth from the ISS. Analysis of photographic images taken from ISS during Expeditions 4 through 11 indicates that most

images taken by crew members were self-initiated (84.5% of 144,180 photographs) and that photography was considered a leisure activity (Robinson et al., in press, as cited by Slack et al., 2008). Long-duration flyer Micheal Lopez-Alegria recently stated, *“Looking out the window and seeing the Earth below, and seeing places you recognize and where you grew up and places you visited has a lot to do with keeping sane, so to speak.”* As of April 2010, approximately 639,000 images had been taken from the ISS (space.com).

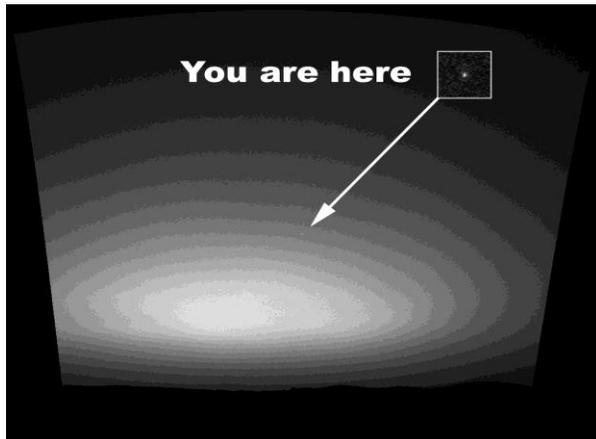


Figure 3: Image of Earth by Mars Spirit Rover

During future exploration missions, Earth will become further from view and may not always be visible in the sky. Photos taken from the surface of Mars demonstrate the negligible presence Earth will have in the night sky (Figure 3). The loss of visual connection to Earth could have a detrimental effect on the psychological well being of crew members (Kanas & Manzey, 2003; 2008).

Plant life will serve as a powerful connection to home during such missions. Cosmonaut Valentin Lebedev of Salyut 7 writes: *“Before going to sleep I watered the pea and oat plants... This is a little space garden. When I smell it, it seems I can smell the Earth. I feel great.”*

Sensory Deprivation

“Monotony of stimulation, even a high level of stimulation can be a serious source of stress.”

Dr. Jack Stuster –From Bold Endeavors: Lessons from Polar and Space Exploration



Figure 4: Stark environment of ISS Exp. 14

Sensory stimulation has long been recognized as a key component of well being for inhabitants of the long-duration ICE environments (Figure 4) (for overview see Stuster, 1996). Depictions of nature, in particular, have been shown to produce a relaxing effect during year-long stays in isolated and confined environments (e.g., Clearwater and Coss, 1991). Given these findings, it is not surprising that scenes of nature are often posted on walls at Antarctic outposts (see Cornelius, 1991).

Living plants can provide:

- Visual stimulation
- Tactile stimulation
- Olfactory stimulation
- Food freshness and variety

Otto (2008) discusses the importance of the station greenhouse during missions to the Antarctic, and cites a McMurdo greenhouse technician as stating, "*Winter is when the greenhouse is most effective. Not only does it grow food for the winter population, but the people are also more deprived.*"



Fresh fruits and vegetables, or “freshies”, are a coveted indulgence among winter-over residents of the Antarctic. The development of a larger greenhouse (*Figure 5*) has created more opportunity for fresh food to be distributed among the winter-over populations at McMurdo station.

Figure 5: McMurdo Greenhouse in Antarctica

The Russian Chamber 105-day study (Mars 105), which featured a greenhouse, offers another look at how plants can be effective at mitigating sensory deprivation. Fresh fruits and vegetables were grown in the greenhouse (*Figures 6 & 7*) and other decorative plants were placed in the main living quarters. During the first month of confinement, 14% of the pictures posted online from within the chamber featured plant life as the focal point. During the second month, 23% of the pictures posted were of plant life. It is plausible that the plants may have represented a psychological connection to the world outside the chamber.



Figure 6: Mars 105 greenhouse



Figure 7: Mars 105 freshly grown tomato

(Source for Figures 6-7: Institute for Biomedical Problems (IBMP) website)

As mission durations increase on board ISS and on expeditions to distant planetary surfaces, countermeasures to mitigate sensory deprivation will be essential to maintaining psychological health.

Nonmedicine Stress Reduction

Ground studies have demonstrated the effects of plants within a built environment on psychological (and physiological) outcomes. Below is a sample of studies on the effect of having plants within a built environment; for a recent literature review see Bringslimark, Hartig, & Patil (2009).

Outcome	NASA Category of Evidence	Author
Reduced stress reactivity, faster stress recovery, and higher reported attentiveness	Category I	Lohr et al. (1996)
Lower perceived stress	Category I	Dijkstra, Pieterse, & Pruyn (2008)
Higher pain tolerance	Category I	Lohr & Pearson-Mims (2000); Patil et al. (2004)
Lower systolic BP and HR day of surgery and 1 st day post-surgery	Category III	Park & Mattson (2008)

Higher reported job satisfaction and overall quality-of-life scores (N=450; controlled for salary, ethnicity, age, gender etc.)	Category III	Dravigne et al (2008)
Higher ratings of mood. Potential increase in cognitive task performance	Category I	Shibata & Suzuki (2002)
Reduction in self-reported symptoms of discomfort	Category III	Fjeld et al. (1998)
Increased reported comfort	Category III	Larsen et al. (1998)
Rooms rated more positively	Category I	e.g., Park & Mattson (2009); Dijkstra, Pieterse, & Pruyn (2008) Lohr & Pearson-Mims (2000); Ke-Tsung Han (2009); Larsen et al. (1998)

The stress-reducing effects of viewing plant life within the built environment are likely to be even more pronounced in the isolated, confined, and extreme environment of long-duration space travel. Astronaut Mike Foale states: *"I loved the greenhouse experiment. I enjoyed looking at [the plants] every morning for about 10 to 15 minutes. It was a moment of quiet time."*

Notably, over the years, a small number of long-duration flyers have even requested that BHP send up an APB (astronaut plant bag), which is a contained plant-growing chamber used by astronauts for recreational "space gardening."

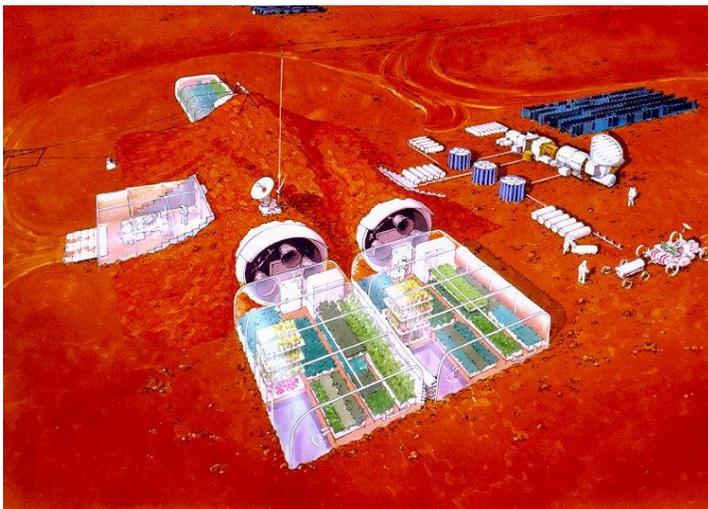
Suggestions for Future Research and Direction



Given the encouraging results of available evidence from space, analogue, and other ground studies, it is recommended that BHP seek out venues to better understand how this topic may relate to the Bmed1 gap and, ultimately, to future exploration missions.

Figure 8: ISS Expedition 13

- The Russian Zvezda Module on ISS contains hardware for plant production (called the Lada “greenhouse”) and is already in use. One U.S./Russian partnership study (Bingham et al., ongoing study) is conducting an interdisciplinary analysis of plant production that includes an assessment of the *“non-nutritional benefits (stress relief, etc.) crew members experience working with plants in space.”* BHP’s involvement in studies such as these is encouraged.
- Given the current plans for improved-capability LED lighting on board ISS, other elements researching plant production will likely be interested in the effects of this lighting on development. If enhanced lighting does become available on ISS, research investigating the effects of different wavelengths of light on plant growth in microgravity could be initiated. Ground studies demonstrate that plants respond mostly to light at wavelengths of approximately 620 nanometers (nm). Authors may wish to collaborate with BHP by combining efforts into a single study, such as in the example of the Bingham et al. (n.d.) study mentioned above. An effort such as this would also advance the Human Research Program’s goal of integration.
- Plant life could be tested in the context of Gap BMed1 in analogue environments such as the Antarctic. One possible study might involve looking at the effects of planned greenhouse visits on sensory deprivation and stress levels. These psychological constructs could be monitored over time during a number of winter-overs and compared to a control group with limited access to the greenhouse.
- Eventual implementation of countermeasures could include recommendations for designers of exploration vehicles to allow for strategically placed spaces for growing plant life. Given that a greenhouse may be integrated into exploration vehicles for food production, BHP may offer recommendations for potential uses of this space for psychological well being. Recommendations for personal “gardens” are another possibility.



*“**Plants** will play an extraordinarily important role in allowing humans to explore destinations like Mars and the moon. They **will provide** food, oxygen, and even **good cheer** to astronauts far from home.”* – NASA Science (2004)

Figure 9: Artist's depiction of a Mars Greenhouse. (Source: NASA Science)